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THE SPECTRA AND PROPER MOTION OF STARS.

By W. H. S. Monck, F. R. A. S.

In the year 1892 I called the attention of the members of this Society to a connexion between the character of the stellar spectra and the proper-motion of the corresponding stars, which I afterward followed up in *Astronomy and Astro-physics* and elsewhere. I had hoped that by this time the Draper catalogue would have been extended to the Southern Stars, which would have enabled this theory to be subjected to a wider test. I recently met with a catalogue which seemed well suited for a test, though, of course, I had only the original Draper catalogue (with some corrections kindly supplied to me by Professor Pickering) to refer to. This was Dr. Rambaut's catalogue of stars observed at Dunsink, consisting mainly of stars with large proper-motion, which were observed with a view of detecting the existence of considerable parallaxes not previously noticed. Dr. Rambaut's limit was an annual motion of 0''.2 in a great circle; but, unfortunately, his catalogue does not contain the entire number of such stars which are capable of being observed at Dunsink (he appears to have limited himself to those respecting which no previous parallactic researches had been made), while it contains a number of stars with less than the requisite amount of proper-motion, which were observed at the request of Dr. Gill, Dr. Downing, and others; and no distinctive mark is applied to stars of this latter class. I soon found that, to select from the catalogue of 717 stars, those whose proper-motion amounted to 0''.2 and upwards would involve a good deal of calculation, and I therefore selected instead those whose proper-motion in Declination exceeded 0''.1. In doing so, no doubt I omitted some stars with a proper-motion of upward of 0''.2, but the omissions were not likely to make much alteration in the relative proportions of the stars with different spectra, with which alone I was concerned. Of the stars thus selected, 92 proved to be Capellan (spectrum E, F, or G), 59 Arcturian (spectrum H, I, K, or L), and only 11 Sirian (spectrum A, B, C, or D). There were very few stars with the spectrum M, and these were all near the lower limit. Thirteen solar stars to each Sirian star is rather a startling proportion, but had I adopted

0″.2 as the motion in Declination, the result would have been still more startling. There would have been *one* Sirian star (marked doubtful in the DRAPER catalogue) to over eighty solars. But Dr. RAMBAUT'S stars were selected without any regard to their spectra, and, I believe, without knowing what the spectra were.

Further, I suspect that several of the eleven Sirian stars in question will prove, on further examination, to be solar stars. For they are usually faint stars, and the DRAPER catalogue often expresses doubt as to the character of their spectra. Their numbers in the DRAPER catalogue are the following: 4637, 4989, 5207 (7 *Sextantis*), 5371, 7088, 8379 (111 *Herculis*), 9039, 9253 (56 *Cygni*), 9328 (5 *Equulei*), 9428, and 9842.

I had previously made a similar examination of the stars in the PULKOVA catalogue having a motion in Declination of over 0″.1 annually, but went over them a second time. These stars, of course, included several whose total proper-motion fell short of 0″.2 per annum, whereas the selected stars from Dr. RAMBAUT'S catalogue contained very few. I obtained (neglecting the notes of interrogation) 27 Sirian stars, 125 Capellan, and 80 Arcturian. The general fact was thus the same as before. I then tried the British Association catalogue for stars with a proper-motion of 0″.1 annually in Declination. The contrast was less strongly marked, probably because several faint stars are erroneously described as Sirian in the DRAPER catalogue. But the three classes of stars came out in the same order, Capellan first, Arcturian second, and Sirian third. This reverses the order in which they occur in the DRAPER catalogue. The Sirians largely outnumber the Arcturians, and the latter somewhat outnumber the Capellans. And taking the PULKOVA catalogue and identifying as many stars as possible with the DRAPER catalogue, I found that more than half were Sirians, and that of the remainder the Arcturians outnumbered the Capellans. But when I came to examine those with large proper-motion only, the relative numbers were reversed. Nor are these Capellan stars, on the average, of higher magnitude than the Sirians or Arcturians. The stellar magnitudes average about the same for all three classes. The fact appears to be — however it may be explained — that Capellan stars have, on the average, larger proper-motion than Arcturians of the same magnitude, and that Arcturian stars have, on the average, much larger proper-motion than Sirians of the same magnitude. The proportion of Capellan stars having a proper-motion in Declination of 0''.1 annually in Declination is ten times as great as that of the Sirians, and twice as great as that of the Arcturians — at least, if we adopt the PULKOVA catalogue as the test. Such is the fact. How is it to be explained? Are the solar stars (and especially the Capellans) moving through space with greater absolute velocity than the Sirian stars? I believe not. There are two tests on this subject: first, the spectroscopic results as regards motion in the line of sight; and, secondly, the result of our investigations on parallax. The latter can hardly be relied on at present, though so far as they go they indicate a larger average parallax for solar stars than for Sirians of the same magnitude. VOGEL'S results as to motion in the line of sight appear more satisfactory, though his list of fifty-one stars contains but six Capellans. Their average motion is 9.5 miles per second, which is somewhat less than the general average. In fact, VOGEL'S observations would lead us to think that all three classes of stars are moving through space with nearly the same velocity. Another reason for arriving at this conclusion is, that the effect of the Sun's motion in space can be traced just as easily in the case of stars with large proper-motion as in the case of stars with small proper-motion; whereas, if the former were really traveling with double or more than double the usual velocity, the effect of the Sun's motion on them would be comparatively small. Are the Capellan stars, then, small stars or dull stars? The latter is, I believe, the true alternative. The great number of double-stars of this type which are known to be binary tends to this result. The smaller the mass of the pair, the slower will be the revolution of the satellite, and the greater will be the difficulty in ascertaining the binary character of the pair and determining the orbit. But I believe it will be found that more than one half of the binary stars whose orbits are approximately known belong to the Capellan type. I pointed out, some years ago, a formula by which the luminosity of two binaries can be compared with each other, assuming that the larger stars were globes of equal density, and their companions very small, compared with them. The result of applying this formula to the Sirian and Capellan binaries whose orbits were supposed to be known was to show that the former were much more luminous than the latter—probably five times as much so. The Arcturian binaries were puzzling. They appeared to occupy both extremes in the scale of luminosity. But the orbits assumed for γ *Leonis* and 61 *Cygni* were probably entirely wide of the mark; and omitting these, they are certainly less luminous than the Sirians; but their position as regards the Capellans is more difficult to define. In fact, there are not enough of them to settle it satisfactorily. There appear to be as many Arcturian as Capellan double-stars, but among known binaries the latter are five or six times as numerous. In like manner, Sirian double-stars are numerous enough, but only a small proportion are known to be binaries. That the vast majority of double-stars are binaries, a careful examination will, I think, lead us to conclude; but good observations on their positions being all of comparatively recent date, we are still without means of proving this fact when the period is very long. Now, *ceteris paribus*, the greater the mass of the pair, the shorter will be the time of revolution; and the shorter periods of revolution in the case of the Capellan double-stars go far to displace the theory that these stars are unusually small. Indeed, unless they are nearer to us than the others, we should be driven to conclude that their masses were greater than those of either the Sirians or the Arcturians. Capellan stars will, I believe, prove not to be the smallest, but the least luminous class of stars—least luminous, at least, relative to their density; for there are some reasons for thinking that a Sirian star, instead of presenting a much brighter surface than a Capellan of the same mass, presents a much greater extent of surface. The Capellan is rather denser than duller; but, mass for mass, it gives much less light.

These results may not be inconsistent with a theory of stellar development, but if so, it must assume a different form from that which would naturally occur to us. If the Sirian, Capellan, and Arcturian stars represent different stages of stellar development, dependent on cooling and condensation, we must place the Capellan stage last, not second. And if stars pass through what is called the third type of spectrum (designated by M in the DRAPER catalogue), they must do so before reaching the Capellan stage. Very few of the stars with this kind of spectrum possess large proper-motion. The number which I have identified in the PULKOVA catalogue is under fifty, some of which are queried; but only four of these have a proper-motion in Declination of over $0''.1$, thus giving a smaller percentage than even the Arcturians. Unless they are, on the average, larger stars than the

Capellans,—and we would not be likely to find the largest stars in the last stage of cooling—they are evidently more luminous, relative to their density, and must, therefore, represent an earlier stage of evolution.

The stars of the Orion type, designated B in the DRAPER catalogue, have less proper-motion than even the ordinary Sirians, denoted by A. On the development theory, they represent the earliest stage, while the Capellans represent the latest. If we cannot represent the development as taking place in this order, the stars must differ in kind—probably composed of different elements. One circumstance which rather favors the theory of development is, that every star of the Algol type whose spectrum I have succeeded in identifying—including those like *Spica Virginis* and *β Aurigæ*, where no actual eclipse at present takes place—are Sirians. On the tidal theory of satellite development, the Algol type of stars belong to the earliest stage, their satellites ultimately developing into the binary systems with moderate periods, which are so frequently found among the the Capellans. The duration of the eclipses in the case of these Algol stars, compared with the intervals between them, indicate a low density for these stars; and this character may not improbably belong to all the Sirian stars. It is possible that, as they become condensed by the cooling process, and their satellites driven to a greater distance by tidal action, they may become Capellans. But, then, where do the Arcturians come in? I can offer no plausible theory on this subject.

In conclusion, I desire to point out that if Sirian stars are, *celeris paribus*, visible at a much greater distance than Arcturians, and the latter visible at a greater distance than Capellans, we must not regard the DRAPER catalogue as indicating the relative frequency with which these classes of stars occur in space. Supposing that the Sirians and Capellans were equally numerous, and that both were uniformly distributed, but that the former were (on the average) visible at double the distance of the latter, we might expect to find eight times as many Sirians as Capellans in the DRAPER catalogue. The actual proportion is about 2½ to 1; and the natural inference appears to be that the Capellan stars are really more numerous than the Sirians. The apparent numerical superiority of the latter is probably a delusive appearance arising from their greater luminosity. And it is evident that in the case of a distant cluster, a number of Sirian stars may be distinctly visible when the light of their Capellan companions is too faint to enable them to be observed separately. This fact should not be lost sight of in speculations relative to the structure of the Galaxy. Certainly, among the nearer stars which are in the same direction as the Galaxy, many (including the famous α *Centauri* and 61 *Cygni*) are of the solar type. Is there any valid reason for regarding the more distant stars in this direction as almost exclusively Sirian? I think not.

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[SUPPLEMENTAL NOTE.]

By W. H. S. Monck.

Having obtained the spectra and proper-motion of a larger number of stars than I had hitherto done by a comparison of the British Association catalogue with the Draper catalogue, I thought it desirable to take the different sub-classes into which Professor Pickering divides the stellar spectra separately. I found a sufficient number of stars with the following spectra to render a comparison feasible; viz. A, B, E, F, G, H, I, K, and M. I compared the proper-motions of the stars of these types (rejecting, in the first instance, all those marked with a note of interrogation in the Draper catalogue) in Declination or North Polar Distance, only ascertaining what proportion of them had a proper-motion of one tenth of a second annually in this direction. All my percentages are somewhat too small, because the divisor included some stars whose proper-motion is not given in the British Association catalogue, but whose spectra I copied into my note-book, with a view of subsequently ascertaining their proper-motions from some other source, which I have not yet done. The percentages which I obtained were as follows:—

Spectrum.	Percentage of stars with requisite motion.
B	0.0
A	8.8
H	16.0
M	16.7
I	18.9
K	22.6
F	31.2
E	31.7
G	40.7